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by

Li Xiao, Chen Hao

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MULTIPLE BEAM SATELLITE BASE BAND SWITCHING STUDY

Li Xiao Chen Hao

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ABSTRACT Studies were done on a type of single stage base band switching network. Stress is laid on the introduction of its single stage storage/repeating structure. Analysis is made of its primary characteristics and limitations. We also derive calculations, and, in conjunction with this, simulate the primary system characteristics and parameters. After that, we put forward, and, in conjunction, carry research a step further on base band switching network structures. Finally, there is a look ahead at appliation prospects associated with the networks.

KEY WORDS Base band switching Switching network Subgroup

FORWARD

During normal operations of multiple beam communications satellites, there is a need to have switching equipment on board the satellite. The switching equipment in question takes signals received from a certain beam area and transfers them to another required beam area. One beam area can have one or multiple surface stations. This switching equipment is generally composed of on board satellite switching matrices and on board satellite distributon and control units.

On board satellite switching matrices are key components connecting satellite multiple beam signals to each other. They can be roughly divided into two types. One type carries out switching with regard to base band signals. At this time, on board satellite repeaters should be regeneration and processing repeaters possessing switching functions. Another type carries out switching with respect to microwave signals. At this time, loaded on repeaters, there are controled switch matrices having switching functions. At the present time, the latter type of method is the more commonly used. On the new INTELSAT VI generation of communication satellites launched by international satellite communications organizations, only this type of microwave switching matrix is loaded.

As far as this type microwave switch matrix is concerned, due to the fact that it is subject to command and control associated with surface stations, there is a possibility that erroneous operations will be produced due to such causes as the reception of erroneous code, and so on. At the same time--in SS-TDMA systems--various surface stations must have unified transfer timing with

satellite switching matrices, thereby controling the times of transmission bursts of the different surface stations so as to guarantee the transiting of switching matrices within correct time periods, setting up frame synchronicity. This is bound to increase surface station equipment costs.

Following along with a constant deepening of research by people with regard to satellite borne signal regeneration processing technologies, people are beginning to try to directly implement the possibility of base band switching on satellites. Option is made for the use of base band switching methods. These are not only capable of saving satellite power. At the same time, they are also able to effectively improve satellite communication encryption characterisitics. Besides this, due to the fact that option is made for the use of such methods as error correction coding, and so on, switching errors can be brought under control. The necessary prerequisite for the realization of on board satellite multiple beam base band switching is signal regeneration processing on satellites.

Generally speaking, on board satellite base band switching networks can be divided into two types [1]. One type is multiple stage switching networks. One type is single stage switching networks. Giving consideration to special circumstances associated with satellite communications, satellite networks should possess such characteristics as small volume, light weight, low power consumption, high reliability, and so on. Summing it up, most of the switching networks made use of by suface subgroup communications nets are mutliple stage switching networks. The reason is that the structures associated with multiple stage switching networks are varied. Switching processes are flexible. As a result, research by various nations with regard to aerial switching equipment is also mostly concentrated on multiple stage networks [2]. However, multiple stage networks also have their own drawbacks. Making comparisons--in order to set up a stable, unblocked multiple stage switching network, the hardware which it is necessary to make use of is almost several times that associated with an unblocked single stage network. At the same time, in a multiple stage network, in order to set up accurate route tables associated with each call currently on hand, the amounts of calculations required are also quite considerable. On the other hand, the route distribution of a single stage switching network is simple. The hardware needed is small. Power consumption is low--characteristics which are clearly more suitable to satellite communications. /7

On board satellite base band switching networks studied in this article are precisely a type of single stage subgroup storage/repeating network appropriate for use in multiple beam satellite subgroup communications.

STRUCTURAL DESIGN OF SATELLITE MULTIPLE BEAM BASE BAND SWITCHING NETWORKS

As is shown in Fig.1, signals associated with various beams

enter into the networks in question in accordance with time division methods of series arrangement. Switching results are also set up in accordance with time division methods of arrangement. This is not only appropriate for use in communications satellites associated with SS-TDMA systems. It can also be suitable for communications satellites associated with FDMA/SS or FDMA/TDMA/SS systems. With regard to FDMA/SS system communications satellites, it is only necessary to respectively add in repeaters associated with TDM frame architecture in front and behind the networks in question. It is also then possible to make use of the same switching networks [3].

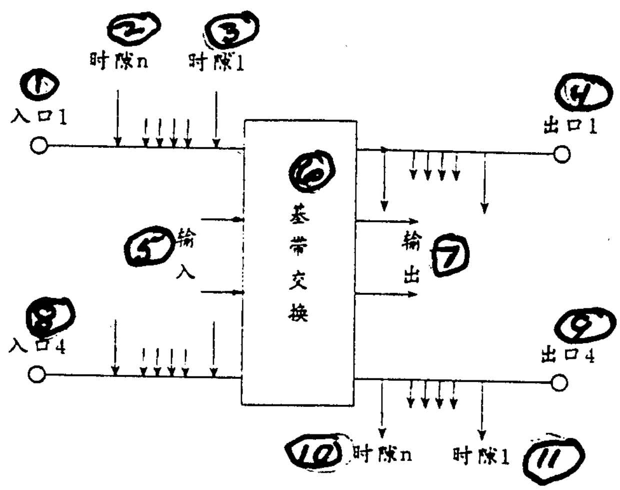

Fig.1 Storage/Repeating Type Time Division Switching Network Schematic

Key: (1) Entry 1 (2) Time Interval n (3) Time Interval 1 (4) Exit 1 (5) Input (6) Base Band Switching (7) Output (8) Entry 4 (9) Exit 4 (10) Time Interval n (11) Time Interval 1

Fig.2 is a line and block chart of the structures associated with the single stage switching networks in question. On the basis of the characteristics of subgroup communications, the data sent by each surface station is subject to division into information groups of fixed lengths. In all cases, each subgroup is transmited and switched independently in networks using repeating methods associated with storage and queueing.

Signal subgroups associated with various beams coming into stations, are arranged into frames in accordance with time division methods. Information frames within coverage areas for each beam are, first of all, stored in memory device 1 in accordance with a certain address sequence. After storing an entire frame of data, there is a turning toward memory device 2 for storage. At the same time, the data in storage device 1 is taken and read out using

appropriate rules, and, in conjunction with that, outputed. As far as store/retrieve speeds associated with control storage devices are concerned, they make it so that when a frame is fully stored in memory device 2, the data in storage device 1 is just completely read. In this way, it is possible to next turn to the storage of data in memory device 1. At the same time, data is read out of storage device 2, and this continues in sequence.

ANALYSIS OF NETWORK CHARACTERISTICS

Among the important performance indices for judging a subgroup switching device are the several below.

- switching time delay
- service processing capabilities
- handling capacity
- reliability

A. Network Time Delays

Transmission time delays associated with information subgroups in networks include queueing times and transmission times associated with information subgroups in output channels. In this network--under ideal circumstances--that is, when the target addresses associated with each different source address of information subgroups are not the same, various subgroups are capable of smoothly going through switching networks. If trunk line output speeds are adequately fast, then, transmission times associated with different subgroups on trunk lines can be ignored in calculations. As a result, transmission delay times associated with various subgroups in networks are only related to store/retrieve times for memory devices. /8

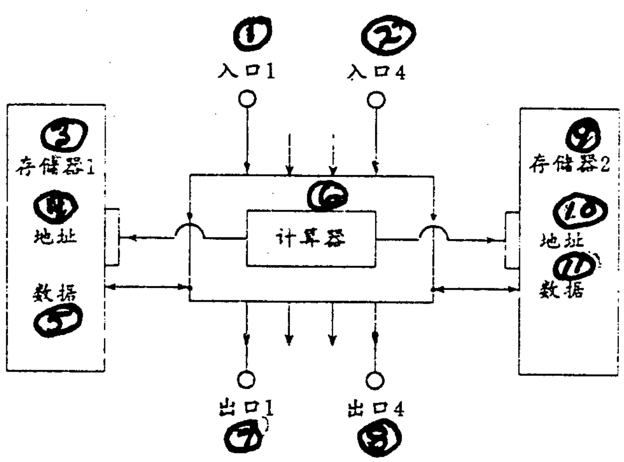

Fig.2 Single Stage Switching Structure Schematic

Key: (1) Entry 1 (2) Entry 2 (3) Storage Device 1 (4) Address (5) Data (6) Computer (7) Exit 1 (8) Exit 2 (9) Storage Device 2 (10) Address (11) Data

Assume that, in each frame, there are included N time intervals and the storage/retrieval time associated with each time interval is the unit time T. Then, the network time delay Tb should form a direct proportion with NxT, that is,

$$Tb = K \times (N \times T) \ (1) \tag{1}$$

In the equation, K is a constant.

B. Network Service Flow Amounts

Assume that each beam entry data input speed is R (bit/s). Then, the service flow amounts associated with the switching networkds in question are:

$$D = R \times M (\text{bit/s}) \tag{2}$$

In this, M is the number of beams.

If the amount of information contained in an information subgroup is J bit, then, the service subgroup flow amount associated with the networks in question (number of subgroups/second) is:

$$\lambda = (R \times M)/J \tag{3}$$

If input data series use 1bit as the unit for read write to memory devices, then, storage device store/retrieve unit time t has the relationship below with service flow amounts:

$$t = \frac{1}{(R \times M)} = \frac{1}{D(s)} \tag{4}$$

That is,

$$D = \frac{1}{t(\text{bit/s})} \tag{5}$$

When trunk line width inputing storage devices is B bit, network service flow amounts are:

$$D = \frac{B}{t(\text{bit/s})} \tag{6}$$

It is possible to see that store/retrieve unit time t directly influences network processing service capabilities. That is nothing else than to say that, when trunk line width is fixed, the maximum service flow amounts which the networks in question are capable of handling are completely determined by storage device unit store/retrieve time t. Fig.3 is the relationship curve between network service flow amount D and store/retrieve time t when B=8bit.

C. Network Handling Capacity

During actual switching processes, ideal conditions where inputed information subgroups do not give rise to collisions in networks are almost incapable of realization. Normally, within the same time frame, there will always be the appearance of one group or several groups of subgroup information with the same addresses. At this time, they will give rise to output conflicts.

In order to avoid information loses given rise to because of information subgroups in switching processes, it is possible to consider adding a sequencing network in front of the base band switching networks in question. The primary function of this sequencing network is to guarantee that the target addresses of various subgroups inputed at one time into switching networks are not the same. Due to limitations carried out with regard to input information subgroups, there are some entries that do not have subgroups to go into networks. Network handling capacities are necessarily influenced.

Assuming that subgroup arrival speeds obey Poisson distributions, we approximately derive the maximum handling capacities of the networks in question--that is, handling capacities associated with switching networks placed in saturated configurations (each time interval entry having subgroups arriving in all cases).

$$\rho = 0.5858 \qquad /9$$

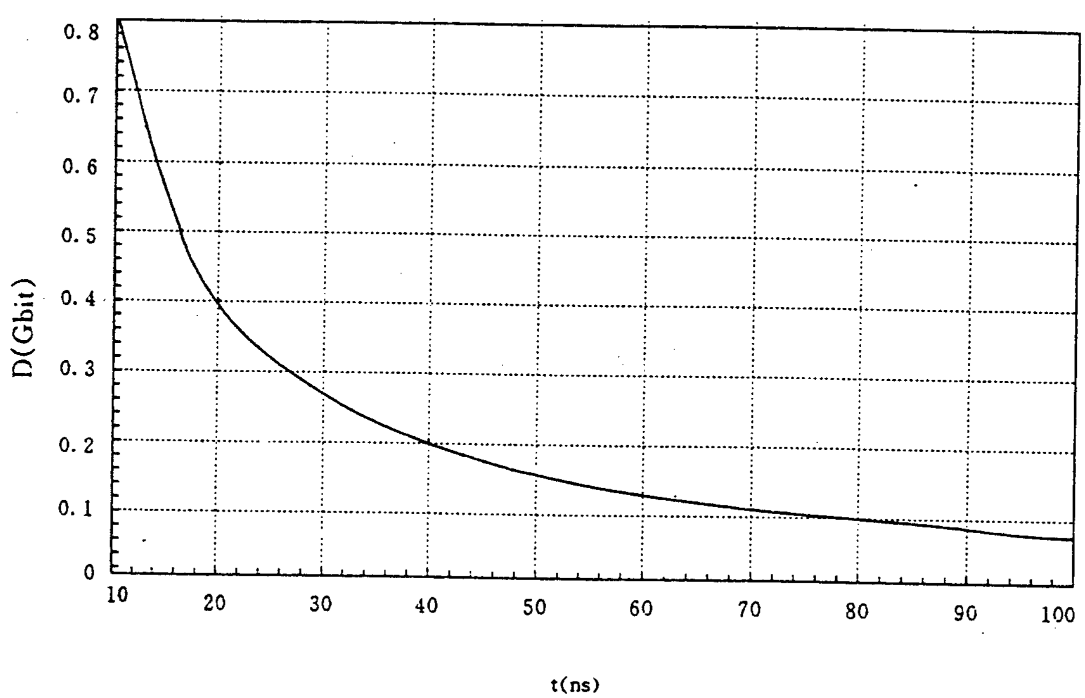

Fig.3 D-t Relationship Curve (B=8)

COMPUTER SIMULATION ANALYSIS

In order to better analyze the single stage switching networks introduced in the section above, we carried out computer simulations and artificial analyses.

Due to limitations in the structures associated with single stage networks, within each time frame, it is only possible to switch one information subgroup to any time interval exit. As a result, among subgroups inputed to the networks, if there is more than one subgroup possessing the same target address, then, there will always be one information subgroup which is lost because of collisions (in accordance with actual simulation rules, it may be that subgroup of information right behind the original address number). A reliable sequencing is capable of guaranteeing that the target address associated with each different information subgroup entering into the switching networks in question are not the same. That is nothing else than to say that there is only one information subgroup sent to any one target address during each switching process, thereby avoiding subgroup collisions and keeping information from being lost. When we carry out network simulations, attention was also paid to this point.

When we structure predetermined subgroup headers, leaving 4bit free spaces, it is possible to make use of the 4bits to act as query/response signals. In these, the first two bits are request signals. The latter two bits are responses signals. Before a certain time interval information subgroup will enter into networks, a request subgroup is first sent toward the network in question. In the subgroup header associated with this subgroup, the first two bits of the query signal are set at 00. In the memory area corresponding to the subgroup target address, computers record this call iteration, setting up a switching agreement. At the same time, the last two bits of the query response signal associated with the subgroup header corresponding to the memory area of the original address is set at 11, standing for the computer response received through output terminals. If it is determined that the call sent out from the original address has already been received, then, normal data subgroups begin to be sent toward the target addresses in question.

If, when subgroup calls are sent, it is discovered that the target address memory area has already been subscribed, then, at the target address location corresponding to the original address the latter two bits of the query response signal will be set at 00. The computer will detect the output 00, that is, it will be notified that the call associated with the original address location has not been received. If it is desired to resend information subgroups associated with the same target address, then, transmission calls must be continued until they get a /10 response and then stop. The process above is as shown in Fig.4.

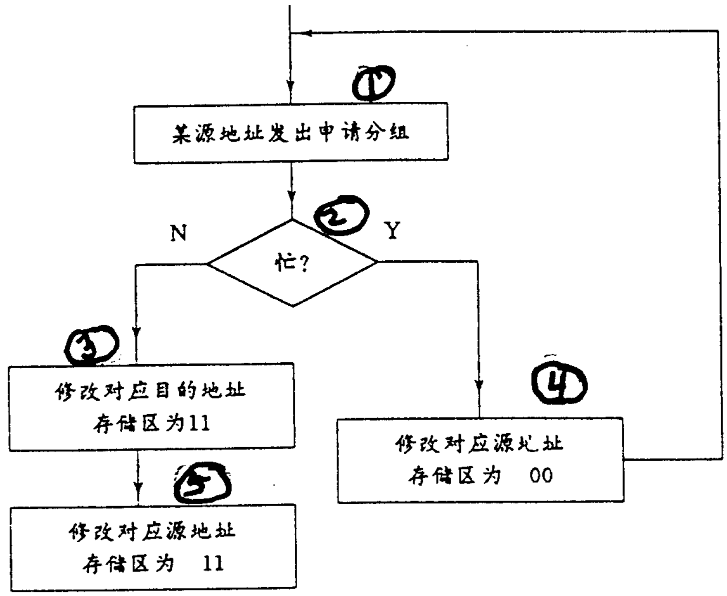

Fig.4 Request Processing Flow Chart

Key: (1) A Certain Original Address Sends Out Request Subgroup (2) Busy? (3) Change Memory Area Corresponding to Target Address to Be 11 (4) Change Memory Area Corresponding to Target Address to Be 00 (5) Change Memory Area Corresponding to Original Address to Be 11

When data transmission to the address in question is completed, a completion subgroup is then sent. This is nothing else than taking the front two bits in query response signals associated with subgroup headers and setting them at 11--standing for completion of transimssion. In conjunction with this, records are made at corresponding target address locations, canceling arrangements, in order to facilitate the sending of calls associated with other original addresses to the target addresses in question. Fig.5 represents this process.

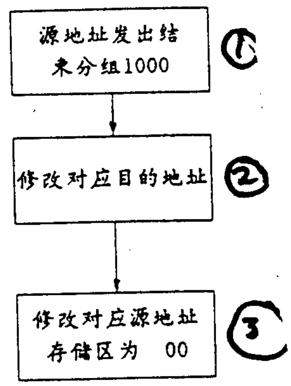

Fig.5 Completion Subgroup Processing Flow Chart

Key: (1) Original Address Sends Out Completion Subgroup 1000 (2) Corresponding Target Address Altered (3) Corresponding Original Address Memory Area Altered to Be 00

Going through this type of processing, each iteration of information subgroup target address entering into networks is, naturally, different--guaranteeing that information subgroups will not be lost because of output collisions.

Fig.6 gives the computer flow chart for the handling of each time frame signal.

SIMULATION PERFORMANCE ANALYSIS

A. Time Delay Results

Above, a theoretical analysis was done of time delays associated with subgroups going through networks, obtaining the relationship between the time delay Tb associated with each subgroup going through switching networks and N:

$$Tb = NT$$

- N is the number of subgroups contained in each time frame.
- T is the store/retrieve time associated with each subgroup.

Using one complete subgroup store/retrieve time as the time unit, it is possible to obtain N-Tb relationship curve diagrams such as Fig.7.

What Fig.7 shows is that computer simulation results and analysis results are in basic agreement with each other. Network time delays are in direct proportion to the number of subgroups N contained within each time frame.

B. Handling Capacity Simulation Results

Table 1 is handling capacity simulation results for the networks in question.

From Table 1, it is possible to see that--eliminating times when the time interval number is 1 and handling capacities and analysis values differ from each other comparatively greatly--other handling capacity simulation values are close to analytical results in all cases. The reason for this is that, when the number of time intervals is too small, subgroup arrival processes are comparatively complicated, and it is not possible to make use of Poisson distributions in order to make approximate formulations.

/11

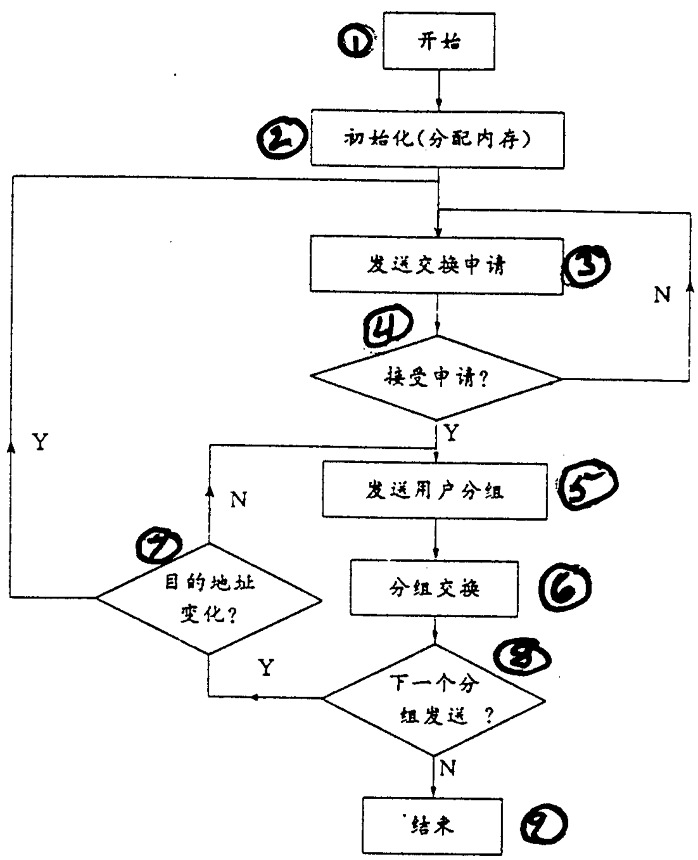

Fig. 6 Simulation Program Flow Chart

Key: (1) Start (2) Initialization (Distribution of Internal Memory) (3) Send Switching Request (4) Request Received? (5) Send User Subgroup (6) Subgroup Switching (7) Target Address Changed? (8) Send Next Subgroup? (9) End

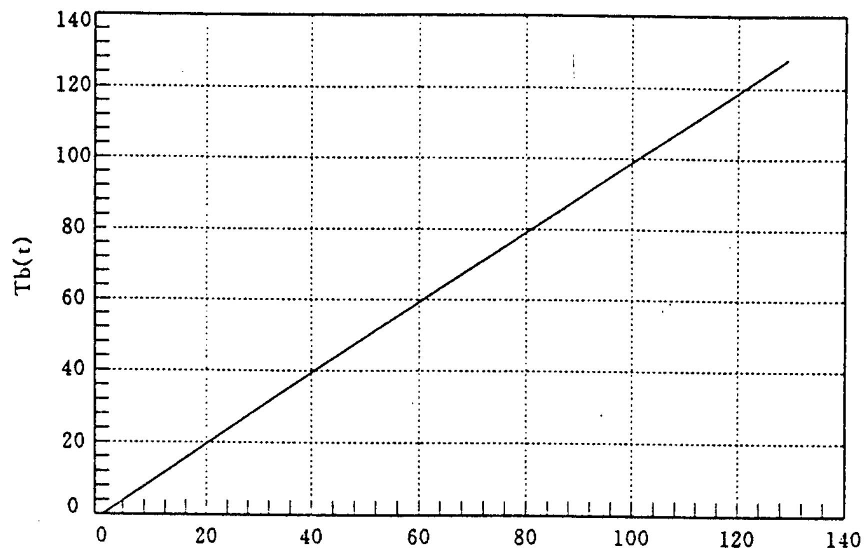

Fig. 7 N-Tb Relationship Curve

Table 1 Handling Capacity Results

Key: (1) Time Intervals Contained in Each Time Frame (2) Number of Subgroups Processed in Each Time Frame (3) Large Scale Handling Capacity

1 每时帧所含时隙	2 每时帧处理分组数	3 量大吞吐量
1	4	0.556250
4	16	0.583750
8	32	0.590000
16	64	0.589922
32	128	0.590117
64	256	0.587617
128	512	0.585547

NETWORK SIMULATIONS ASSOCIATED WITH TMS320C30

In order to better simulate network switching processes--making them more comprehensive and more realistic, and, in conjunction with that, to improve the speed of switching simulations--we made use of ATD-C30-A model artificial systems to carry out a number of simulations.

Diagram 8 is the flow chart associated with network simulations on TMS320C30.

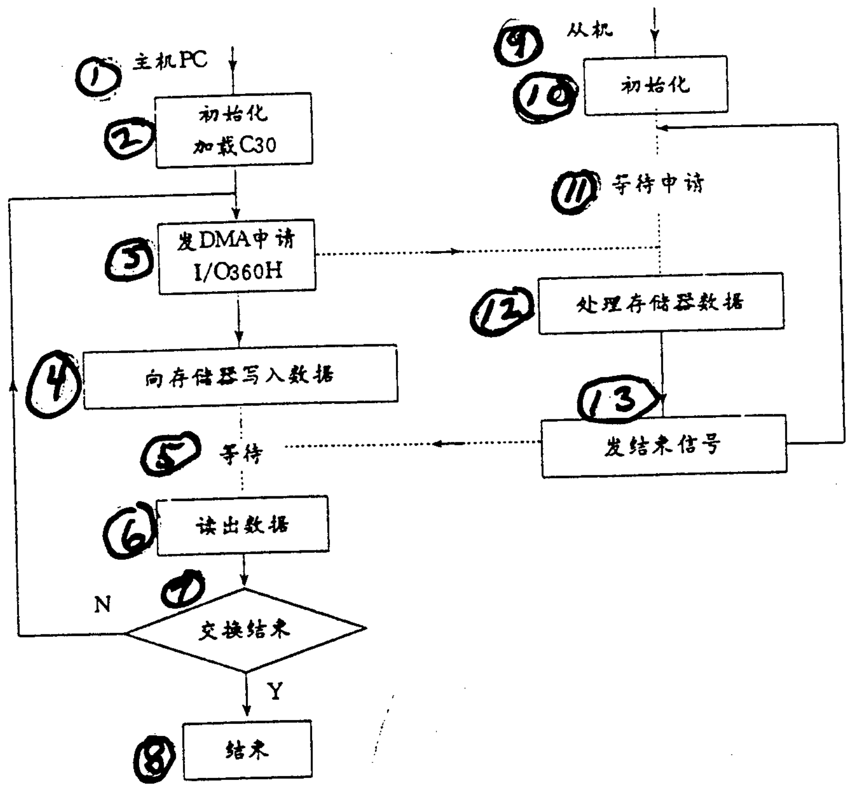

Fig.8 Simulation Process Flow Chart

Key: (1) Master PC (2) Initialization Add Load C30 (3) Send DMA Request I/O360H (4) Write Data into Memory (5) Wait (6) Read Out Data (7) Switching Completed (8) End (9) Slave Unit (10) Initialization (11) Await Request (12) Process Memory Data (13) Send Completion Signal

During simulation switching processes on TMS320C30, data switching speeds very, very greatly increase, receiving anticipated results.

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A TYPE OF IMPROVED SINGLE STAGE NETWORK STRUCTURE

Actual handling capacities of single stage switching networks are certainly not large. Maximum handling capacities are 0.5858 . In order to improve actual handling capabilities of networks and reduce output collisions in networks, it is possible to give some consideration to taking several information subgroups possessing the same target address and outputing them to target addresses that are unused. This is one type of comparatively active solution method. Opting for the use of this type of method, it is possible to more fully and effectively make use of various switching signal channels--improving network utilization rates.

Going through analyses, we learn that, after improvements, network handling capacities are capable of improving original networks approximately 0.13:

$$\rho = 0.6854$$

We carried out simulations of network handling capacities in accordance with improved network structures. The results were as shown in Table 2. Handling capacity simulation results will improve close to 17% compared to original networks. This approximates analytical results.

Table 2 Improved Network Handling Capacity Simulation Results

Key: (1) Number of Time Intervals Included in Each Time Frame (2) Maximum Handling Capacity

1 每时帧所含时隙数	最大吞吐量 2
1	0.740000
4	0.728750
8	0.713750
16	0.695781
32	0.687266
64	0.687617
128	0.692070

Table 3 Improved Network Output Terminal Average Queueing Lengths

Key: (1) Time Intervals Included in Each Time Frame (2) Average Queue Length

1 每时帧所含时隙	平均队长 2
4	0.5969375
8	0.5151875
16	0.4711720
32	0.4368761
64	0.4253657
128	0.4052730

Due to the fact that during one iteration of network switching after improvements, it is possible to take multiple subgroups and output them to the same time interval exit. As a result, it is necessary to add output buffers to output terminals. In order to shorten overall buffer length, it is possible to install a type of shared output buffer [4].

Improvement plans use increasing output buffers as the price for improving network handling capacities. As a result, there is a need to make analyses of overall buffer lengths.

Going through analyses, it is possible to solve for each output terminal queueing length.

$$1 \quad = 0.382363$$

Table 3 is average queue length obtained for each terminal associated with computer simulations.

Improved network handling capacities show relatively large improvements compared to original networks. Moreover, added output buffer length is approximately 40% of the length of one buffer in original networks. The addition of buffers with this kind of length should be acceptable. /14

PROSPECTS FOR APPLICATIONS

The single stage networks associated with this study are aimed at 4 beam satellite networks. In actual applications, when numbers of satellite beams are comparatively great, expansion of networks is also very easy. Fig.9 is a satellite switching network expansion schematic. It takes four 4x4 switching networks and expands them to become one 8x8 switching network. As far as the development of satellite borne processing technology associated with Chinese satellites is concerned, it makes us have reason to believe that, in the not too distant future, a day will be seen with the practical application of base band switching networks in Chinese multiple beam satellite communications.

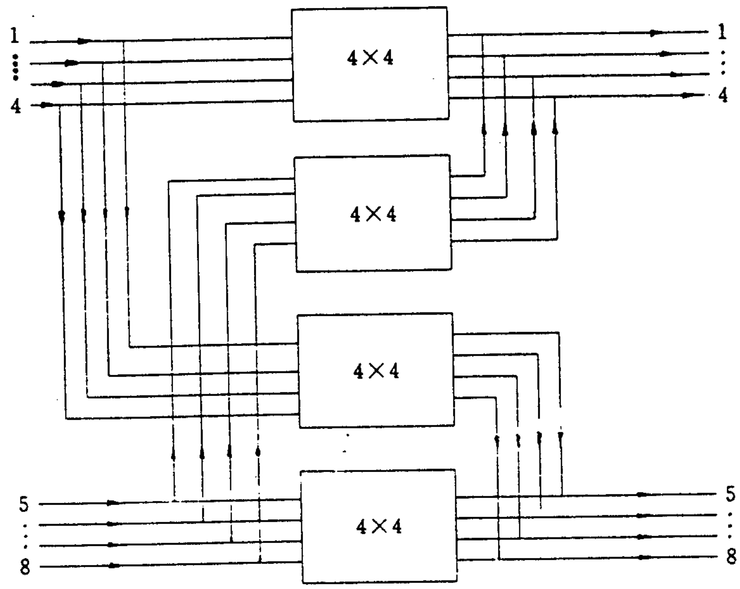

Fig.9 Single Stage Switching Network Expansion

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